

Higgs decay to dark matter in low energy SUSY: is it detectable at the LHC ?

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Abstract

Due to the limited statistics so far accumulated in the Higgs boson search at the LHC, the Higgs boson property has not yet been tightly constrained and it is still allowed for the Higgs boson to decay invisibly to dark matter with a sizable branching ratio. In this work, we perform a comparative study for the Higgs decay to neutralino dark matter by considering three different low energy SUSY models: the minimal supersymmetric standard model (MSSM), the next-to-minimal supersymmetric standard models (NMSSM) and the nearly minimal supersymmetric standard model (nMSSM). Under current experimental constraints at 2σ level (including the muon $g - 2$ and the dark matter relic density), we scan over the parameter space of each model. Then in the allowed parameter space we calculate the branching ratio of the SM-like Higgs decay to neutralino dark matter and examine its observability at the LHC by considering three production channels: the weak boson fusion $VV \rightarrow h$, the associated production with a Z-boson $pp \rightarrow hZ + X$ or a pair of top quarks $pp \rightarrow ht\bar{t} + X$. We find that in the MSSM such a decay is far below the detectable level; while in both the NMSSM and nMSSM the decay branching ratio can be large enough to be observable at the LHC. We conclude that at the LHC the interplay of detecting such an invisible decay and the visible di-photon decay may allow for a discrimination of different SUSY models.

PACS numbers: 14.80.Da, 14.80.Ly, 12.60.Jv

I. INTRODUCTION

As a cornerstone of the standard model (SM) and also the last undiscovered piece, the Higgs boson has been intensively searched in collider experiments. The foregone colliders LEP II and Tevatron yielded null search results, setting a lower bound of 114.4 GeV on the Higgs mass [1] and excluding a Higgs boson with a mass around $2M_W$ [2], respectively. The ongoing Large Hadron Collider (LHC) took over the Higgs-hunting task and recently reported its search results. Based on an integrated luminosity of 4.9 fb^{-1} collected at $\sqrt{s} = 7\text{TeV}$, the two experimental groups at the LHC independently further narrowed down the Higgs mass region (at 95% C.L. the CMS collaboration excluded 127-600 GeV while the ATLAS collaboration excluded 112.9-115.5 GeV, 131-238 GeV and 251-466 GeV) and both hinted to a Higgs boson around 125 GeV [3]. Such a finding has stimulated some theoretical studies for a Higgs boson near 125 GeV in low energy supersymmetry [4] and other models [5].

Of course, if the LHC hint of a 125 GeV Higgs from the di-photon channel is confirmed in the future, it would severely constrain or exclude those new physics models in which some new exotic decay modes (such as decaying invisibly into dark matter) are open and the di-photon rate is suppressed. But so far the statistics at the LHC is too small to confirm such a Higgs, let alone the precision measurement of the Higgs decay branching ratios. Therefore, experimentally it is still allowed for the Higgs boson to decay exotically, such as invisibly to dark matter, with a sizable branching ratio ¹.

Theoretically, the Higgs decay to dark matter can indeed occur in some new physics models, such as the gauge singlet extensions of the SM [7], the SM with a heavy fourth generation [8], the large extra dimension model [9], the technicolor model [10], the spontaneously broken R-parity models [11] and the non-linearly realized supersymmetric model [12] and the MSSM with a singlet [13]. In this work, we perform a comparative study for the Higgs decay to neutralino dark matter in low energy SUSY by considering three different models: the minimal supersymmetric standard model (MSSM) [14–16], the next-to-minimal supersymmetric standard models (NMSSM) [17, 18] and the nearly minimal supersymmetric

¹ In [6] the authors used the limited LHC statistics of the di-photon signal rates to set constraints on the invisible Higgs decay in the MSSM and found that the invisible Higgs decay branching ratio around 10% is allowed.

standard model (nMSSM) [19–21]. As will be shown, in both the NMSSM and nMSSM, the SM-like Higgs boson can decay to neutralino dark matter with a sizable branching ratio.

In case that the Higgs boson decays to dark matter with a sizable branching ratio, detecting such a decay at the LHC will be important because in this case the conventional visible decays into $\gamma\gamma$, $b\bar{b}$, $\tau\bar{\tau}$, $WW^{(*)}$ and $ZZ^{(*)}$ are often suppressed. Obviously, the main production channel via gluon fusion $gg \rightarrow h$ is not usable because it just gives missing energy. It was found through Monte Carlo simulations that the production via vector boson fusion (VBF) $pp \rightarrow hqq'$ and the associated productions $pp \rightarrow hZ$ and $pp \rightarrow ht\bar{t}$ can offer the opportunity to detect the Higgs decay to dark matter [22–26]. So in this work we choose these three production channels to display the observability of Higgs decay to dark matter in low energy SUSY.

Note that although in the literature the Higgs decay to neutralino dark matter has been discussed in some specific model like MSSM, it is necessary to give a revisit in low energy SUSY for two reasons: (i) Different SUSY models usually give rather different phenomenology and it is interesting to perform a comparative study for different models; (ii) We want to know in the SUSY parameter space allowed by current experiments whether or not the Higgs decay to neutralino dark matter is detectable at the LHC. If in some model this decay is found to be accessible at the LHC, we further want to know how large the parameter space can be covered by searching for such an invisible decay at the LHC.

This work is organized as follows. In Sec. II, we briefly describe the three supersymmetric models. In Sec. III, through a scan over the parameter space we present the branching ratio of Higgs decay to neutralino dark matter and show the observability at the LHC. Finally, the conclusion is given in Sec. IV.

II. THE SUSY MODELS

In a renormalizable supersymmetric field theory, the interactions and masses of all particles are determined by their gauge transformation properties and superpotential. The superpotential is a holomorphic function of chiral superfields $\hat{\Phi}_i \supset (\phi_i, \psi_i, F_i)$, with ϕ_i , ψ_i and F_i being respectively the bosonic, fermionic and auxiliary fields, and takes a form [15]

$$W = L^i \hat{\Phi}_i + \frac{1}{2} M^{ij} \hat{\Phi}_i \hat{\Phi}_j + \frac{1}{6} g^{ijk} \hat{\Phi}_i \hat{\Phi}_j \hat{\Phi}_k \quad (1)$$

where the parameters L_i should be of dimension $[mass]^2$ and is only allowed if $\hat{\Phi}_i$ is a gauge singlet. The mass matrix M^{ij} can only be non-zero when the supermultiplets $\hat{\Phi}_i$ and $\hat{\Phi}_j$ are conjugates of each other under gauge transformation. And the massless coefficients y^{ijk} can only be non-zero when $\hat{\Phi}_i\hat{\Phi}_j\hat{\Phi}_k$ formed a gauge singlet.

The MSSM is the most economized realization of supersymmetry in particle physics, which has two Higgs doublets \hat{H}_u and \hat{H}_d and its superpotential is given by [15]

$$W^{MSSM} = W_F + \mu \hat{H}_u \cdot \hat{H}_d, \quad (2)$$

with W_F given by

$$W_F = \bar{u}Y_u\hat{Q} \cdot \hat{H}_u - \bar{d}Y_d\hat{Q} \cdot \hat{H}_d - \bar{e}Y_e\hat{L} \cdot \hat{H}_d. \quad (3)$$

The MSSM has the so-called μ -problem, which can be solved in some extensions by introducing a Higgs singlet \hat{S} . Among these extensions the most popular ones are the NMSSM and nMSSM, whose superpotentials are [17, 19]

$$W^{NMSSM} = W_F + \lambda \hat{S} \hat{H}_u \cdot \hat{H}_d + \frac{\kappa}{3} \hat{S}^3; \quad (4)$$

$$W^{nMSSM} = W_F + \lambda \hat{S} \hat{H}_u \cdot \hat{H}_d + \xi_F M_n^2 \hat{S}. \quad (5)$$

The scalar potential in the Lagrangian contains the so-called F-term, D-term and soft-term [27]:

$$V^{SUSY} = V_F + V_D + V_{soft}, \quad (6)$$

where

$$V_F = F^{*i}F_i, F^{*i} = -W^i = -\frac{\delta W}{\delta \hat{\Phi}_i}; \quad (7)$$

$$V_D = \frac{G^2}{8}(|H_d|^2 - |H_u|^2)^2 + \frac{g_2^2}{2}(|H_d|^2|H_u|^2 - |H_u \cdot H_d|^2); \quad (8)$$

$$V_{\text{soft}}^{MSSM} = \tilde{m}_{H_u}^2 |H_u|^2 + \tilde{m}_{H_d}^2 |H_d|^2 + (B_\mu H_u \cdot H_d + h.c.); \quad (9)$$

$$V_{\text{soft}}^{NMSSM} = \tilde{m}_{H_u}^2 |H_u|^2 + \tilde{m}_{H_d}^2 |H_d|^2 + \tilde{m}_S^2 |S|^2 + (\lambda A_\lambda S H_u \cdot H_d + \frac{\kappa}{3} A_\kappa S^3 + h.c.) \quad (10)$$

$$V_{\text{soft}}^{nMSSM} = \tilde{m}_{H_u}^2 |H_u|^2 + \tilde{m}_{H_d}^2 |H_d|^2 + \tilde{m}_S^2 |S|^2 + (\lambda A_\lambda S H_u \cdot H_d + \xi_S M_n^2 \hat{S} + h.c.) \quad (11)$$

Here the parameter G is defined as $G^2 = g_1^2 + g_2^2$ with g_1 and g_2 denoting respectively the $U(1)_Y$ and $SU(2)_L$ couplings. With the Higgs fields H_u , H_d and S developing respectively

the VEV v_u , v_d and v_S , they can be rewritten as

$$H_u = \begin{pmatrix} H_u^+ \\ \frac{v_u + \phi_u + i\varphi_u}{\sqrt{2}} \end{pmatrix}, H_d = \begin{pmatrix} \frac{v_d + \phi_d + i\varphi_d}{\sqrt{2}} \\ H_d^- \end{pmatrix}, S = \frac{v_S + \phi_S + i\varphi_S}{\sqrt{2}} \quad (12)$$

In both the NMSSM and nMSSM we have five complex scalar fields or ten real scalar degrees of freedom, whose mass eigenstates are obtained as

$$\begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix} = S_{ij} \begin{pmatrix} \phi_u \\ \phi_d \\ \phi_S \end{pmatrix}, \begin{pmatrix} a_1 \\ a_2 \\ G^0 \end{pmatrix} = P_{i,j} \begin{pmatrix} \varphi_u \\ \varphi_d \\ \varphi_S \end{pmatrix}, \begin{pmatrix} H^+ \\ G^+ \end{pmatrix} = C_{ij} \begin{pmatrix} H_u^+ \\ H_d^+ \end{pmatrix} \quad (13)$$

Here the three Goldstone bosons G^0 and G^\pm will be eaten by the weak gauge bosons Z and W^\pm respectively. Then we have seven Higgs bosons, among which h_1 , h_2 and h_3 are CP-even (with the convention $m_{h_1} < m_{h_2} < m_{h_3}$), a_1 and a_2 are CP-odd (ordered as $m_{a_1} < m_{a_2}$), and H^\pm are the charged ones.

In the NMSSM and nMSSM there are five neutralinos (χ_i^0), which are the mixture of bino (\tilde{B}), wino (\tilde{W}^0), higgsino (\tilde{H}_u, \tilde{H}_d) and singlino (\tilde{S}):

$$\begin{pmatrix} \chi_1^0 \\ \chi_2^0 \\ \chi_3^0 \\ \chi_4^0 \\ \chi_5^0 \end{pmatrix} = N_{ij} \begin{pmatrix} \tilde{B} \\ \tilde{W}^0 \\ \tilde{H}_u \\ \tilde{H}_d \\ \tilde{S} \end{pmatrix} \quad (14)$$

We assume the lightest neutralino is the lightest supersymmetric particle (LSP) and make up of the cosmic dark matter.

For the purpose of our numerical analysis, we present the interactions of the Higgs bosons h_i with $b\bar{b}$, $\tau\tau$, WW and $\chi_1^0\chi_1^0$. In the the NMSSM, they are given by [28]

$$h_i b_L b_R^c : \quad \frac{m_b}{\sqrt{2}v \cos \beta} S_{i2} \quad (15)$$

$$h_i \tau_L \tau_R^c : \quad \frac{m_\tau}{\sqrt{2}v \sin \beta} S_{i1} \quad (16)$$

$$h_i W_\mu^+ W_\nu^- : \quad g_{\mu\nu} \frac{g_2^2}{\sqrt{2}} (h_u S_{i1} + h_d S_{i2}) \quad (17)$$

$$h_i \chi_1^0 \chi_1^0 : \quad \frac{\lambda}{\sqrt{2}} (S_{i1} \Pi_{11}^{45} + S_{i2} \Pi_{11}^{35} + S_{i3} \Pi_{11}^{34}) - \sqrt{2} \kappa S_{i3} N_{15} N_{15} \\ - \frac{g_1}{2} (S_{i1} \Pi_{11}^{13} - S_{i2} \Pi_{11}^{14}) + \frac{g_2}{2} (S_{i1} \Pi_{11}^{23} - S_{i2} \Pi_{11}^{24}) \quad (18)$$

where $\Pi_{11}^{ij} = N_{1i}N_{1j} + N_{1j}N_{1i}$. The corresponding couplings in the nMSSM can be obtained by setting κ equal to zero (for MSSM, setting κ , λ , S_{13} and N_{15} to zero).

For the NMSSM, in the basis $\chi^0 = (\tilde{B}, \tilde{W}^0, \tilde{H}_u, \tilde{H}_d, \tilde{S})$, the tree-level neutralino mass matrix takes the form [17, 28]

$$M_{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & \frac{g_1 v_u}{\sqrt{2}} & -\frac{g_1 v_d}{\sqrt{2}} & 0 \\ 0 & M_2 & -\frac{g_2 v_u}{\sqrt{2}} & \frac{g_2 v_d}{\sqrt{2}} & 0 \\ \frac{g_1 v_u}{\sqrt{2}} & -\frac{g_2 v_u}{\sqrt{2}} & 0 & -\mu & -\lambda v_d \\ -\frac{g_1 v_d}{\sqrt{2}} & \frac{g_2 v_d}{\sqrt{2}} & -\mu & 0 & -\lambda v_u \\ 0 & 0 & -\lambda v_d & -\lambda v_u & 2\kappa S \end{pmatrix} \quad (19)$$

The corresponding mass matrix for the MSSM can be obtained by taking the upper 4×4 matrix from the above expression, and for the nMSSM it can be obtained by set the term $2\kappa S$ to zero. When $|\mu_{eff}|$ or $M_2 \gg M_Z$, the lightest neutralino in the MSSM becomes bino-like, with a mass given by [15]

$$m_{\chi_1^0} \simeq M_1 - \frac{m_z^2 \sin^2 \theta_w (M_1 + \mu \sin 2\beta)}{\mu^2 - M_1^2} \quad (20)$$

In the nMSSM the lightest neutralino is singlino-like and its mass can be approximated as [20]

$$m_{\chi_1^0} \simeq \frac{2\mu\lambda^2(v_u^2 + v_d^2)}{2\mu^2 + \lambda^2(v_u^2 + v_d^2)} \frac{\tan \beta}{\tan^2 \beta + 1}. \quad (21)$$

III. NUMERICAL RESULTS AND DISCUSSIONS

We scan over the parameter space of each model under current experiment constraints, and for each survived sample we calculate the Higgs spectrum, decay branching ratios and production rates at the LHC. In our calculation we use the package NMSSMTools [28] and extend it to the nMSSM [21]. For the calculation of $h \rightarrow \gamma\gamma$ in the SM, we use the package Hdecay [29]. For the Higgs production cross sections, we use the code on the website [30] (this code is aimed at the MSSM, and we extend it to the NMSSM and the nMSSM). For parton distributions we use CTEQ6L [31] with the renormalization scale and the factorization scale chosen to be the sum of the masses of the produced particles.

In our scan we require the models to explain the cosmic dark matter relic density measured by WMAP [32] and also explain the muon anomalous magnetic moment at 2σ level. In addition, we consider the following experimental constraints:

1. The LEP bounds on sparticle masses and on the Higgs sector from $e^+e^- \rightarrow hZ(hA)$ followed by $Z \rightarrow \ell^+\ell^-$, $\chi_1^0\chi_1^0$, $h \rightarrow b\bar{b}$ and $\tau^+\tau^-$ [33]; We also consider the LEP-I constraints on the invisible Z decay ², i.e., $\Gamma(Z \rightarrow \chi_1^0\chi_1^0) < 1.76$ MeV, and the LEP-II constraints on neutralino production $\sigma(e^+e^- \rightarrow \chi_1^0\chi_i^0) < 10^{-2}$ pb ($i > 1$) and $\sigma(e^+e^- \rightarrow \chi_i^0\chi_j^0) < 10^{-1}$ pb ($i, j > 1$) [33].
2. The Tevatron bounds on sparticle masses and on stop or sbottom pair production followed by $\tilde{t} \rightarrow c\chi$, $b\tilde{l}\tilde{\nu}_l$ and $\tilde{b} \rightarrow b\chi$ [34, 35];
3. The recent LHC bounds on the Higgs sector from the measurement of the signal rates of $\gamma\gamma$, $\tau\tau$, $WW^{(*)}$ and $ZZ^{(*)}$ [36, 37];
4. The constraints from B-physics, such as $b \rightarrow s\gamma$ and $B_s \rightarrow \mu\mu$ [38];
5. The electroweak precision observables like M_W , $\sin^2\theta_W$ and R_b [39].

In order to reduce the number of free parameters, for the gaugino masses we assume the grand unification relation $3M_1/5\alpha_1 = M_2/\alpha_2 = M_3/\alpha_3$ and thus we have only one gaugino mass parameter (we choose M_2 in our calculation). In order to explain the muon anomalous magnetic moment at 2σ level for moderate $\tan\beta$ (≤ 20), for the smuon sector we assume the soft-breaking parameters to be 100 GeV [21]. For other soft-breaking parameters in the squark and slepton sectors, we assume them to be 1 TeV except that for the MSSM we allow the third-generation squark mass parameters $m_{\tilde{q}}$ to vary in a wide range. The parameter M_n in the superpotential of the nMSSM is also fixed to be 1 TeV. Other parameters are scanned in the following ranges (among which M_a is the mass of the $\cos\beta\varphi_u + \sin\beta\varphi_d$ field, i.e., the diagonal element of the doublet in the CP-odd Higgs mass matrix):

1. For the MSSM: $1 < \tan\beta < 20$, $100 \text{ GeV} < \mu < 600 \text{ GeV}$, $10 \text{ GeV} < M_2 < 200 \text{ GeV}$, $500 \text{ GeV} < M_a < 3 \text{ TeV}$, $100 \text{ GeV} < M_{\tilde{q}} < 2 \text{ TeV}$, $-3 \text{ TeV} < A_{t,b} < 3 \text{ TeV}$. In this space we scan two million random points and about three thousands points survived the experimental constraints.

² Note that the constraints from such an invisible Z decay are stringent for a wino-like or higgsino-like neutralino, but become quite weak for a bino-like or singlino-like neutralino.

2. For the NMSSM: $0.1 < \lambda < 0.7$, $0.1 < \kappa < 0.5$, $1 < \tan \beta < 4$, $100 \text{ GeV} < (\mu, M_a) < 1 \text{ TeV}$, $50 \text{ GeV} < M_2 < 150 \text{ GeV}$, $0 < A_\lambda < 1 \text{ TeV}$, $-500 \text{ GeV} < A_\kappa < 0$. In this space we scan ten million random points and about one thousand points survived.
3. For the nMSSM: $0.1 < \lambda < 0.7$, $1 < \tan \beta < 10$, $50 \text{ GeV} < (\mu, M_2, M_a) < 1 \text{ TeV}$, $0 < A_\lambda < 1 \text{ TeV}$, $0 < M_{\tilde{S}} < 500 \text{ GeV}$, $-1 < \xi_F < 1$. In this space we scan one billion random points and about 2 thousands points survived.

Note that our scan is not a general scan over the entire parameter space. Since our purpose is to figure out if the invisible decay of the Higgs boson is accessible at the LHC, we only scanned over a part of parameter space which is potentially able to allow for a light neutralino and hence the Higgs can decay into the neutralino pair.

In Figs. 1 and 2 we display the scatter plots of the parameter space which survive all constraints. Fig. 1 shows the Higgs decay branching ratios and the LHC (7 TeV) di-photon rate, while Fig. 2 shows the observability of the decay $h \rightarrow \chi_1^0 \chi_1^0$ through three production channels at the LHC (7 TeV). The 2σ sensitivity of the ATLAS detector shown in Fig. 2 is obtained from a Monte Carlo simulation carried out in [23–25]. For the decay $h \rightarrow \chi_1^0 \chi_1^0$, the signature of the production via vector boson fusion $VV \rightarrow h$ is two far forward and backward tagging jets of moderate p_T with considerable missing momentum \cancel{p}_T in the central region. For the productions $pp \rightarrow hZ$ and $pp \rightarrow h t \bar{t}$, the signatures are obvious: for the former it is two isolated high p_T leptons from the Z-boson decay and large missing \cancel{p}_T from the Higgs decay; for the latter it is di-leptons (or lepton plus jets) and large missing \cancel{p}_T .

From these figures we obtain the following findings:

- In each model the SM-like Higgs can have a mass near 125 GeV, as hinted by the recent LHC results.
- In the MSSM the SM-like Higgs boson dominantly decays to $b\bar{b}$ (just like in the SM), the decay $h \rightarrow \chi_1^0 \chi_1^0$ has a very small branching ratio (below about 10%), and the di-photon signal rate is close to the SM value. Due to the small branching ratio, the Higgs decay $h \rightarrow \chi_1^0 \chi_1^0$ is far below the detectable level.
- In the NMSSM the decay $h_1 \rightarrow \chi_1^0 \chi_1^0$ can be comparable to $h_1 \rightarrow b\bar{b}$. In the region with a sizable decay ratio of $h_1 \rightarrow \chi_1^0 \chi_1^0$, the lightest neutralino χ_1^0 is rather light (below $h_1/2$) and the coupling of h_1 to χ_1^0 is large (see Eq. 18). The diphoton signal rate can

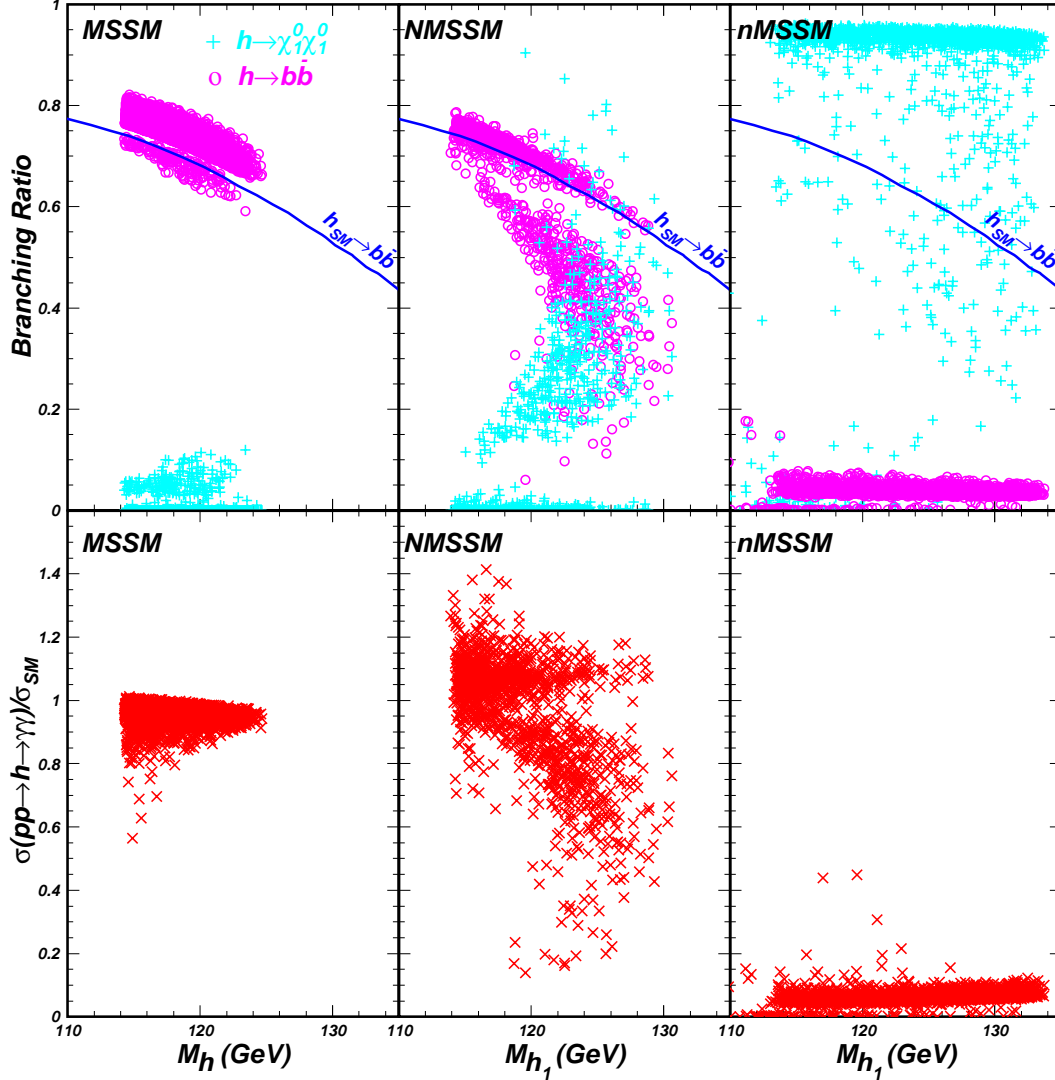


FIG. 1: The scatter plots of the parameter space which survive all constraints listed in the text. In the upper frames, the samples denoted by crosses (sky-blue) show the branching ratio of $h \rightarrow \chi_1^0 \chi_1^0$ while the samples denoted by circle (magenta) show the branching ratio of $h \rightarrow b\bar{b}$. The solid curves (blue) denote the SM prediction for the branching ratio of $h \rightarrow b\bar{b}$. In the lower frames, the samples denoted by times (red) show the ratio $\sigma_{SUSY}(pp \rightarrow h \rightarrow \gamma\gamma)/\sigma_{SM}(pp \rightarrow h \rightarrow \gamma\gamma)$ at the LHC (7 TeV). In this figure and below, ' h_{SM} ' denotes the Higgs boson in the SM, ' h ' denotes the lightest neutral Higgs boson in the MSSM, and ' h_1 ' denotes the SM-like Higgs boson in the NMSSM and nMSSM (the doublet component of h_1 is over 60%).

be sizably deviate from the SM prediction, either enhanced or suppressed significantly. In a large part of the parameter space, the Higgs decay $h_1 \rightarrow \chi_1^0 \chi_1^0$ is accessible at the LHC.

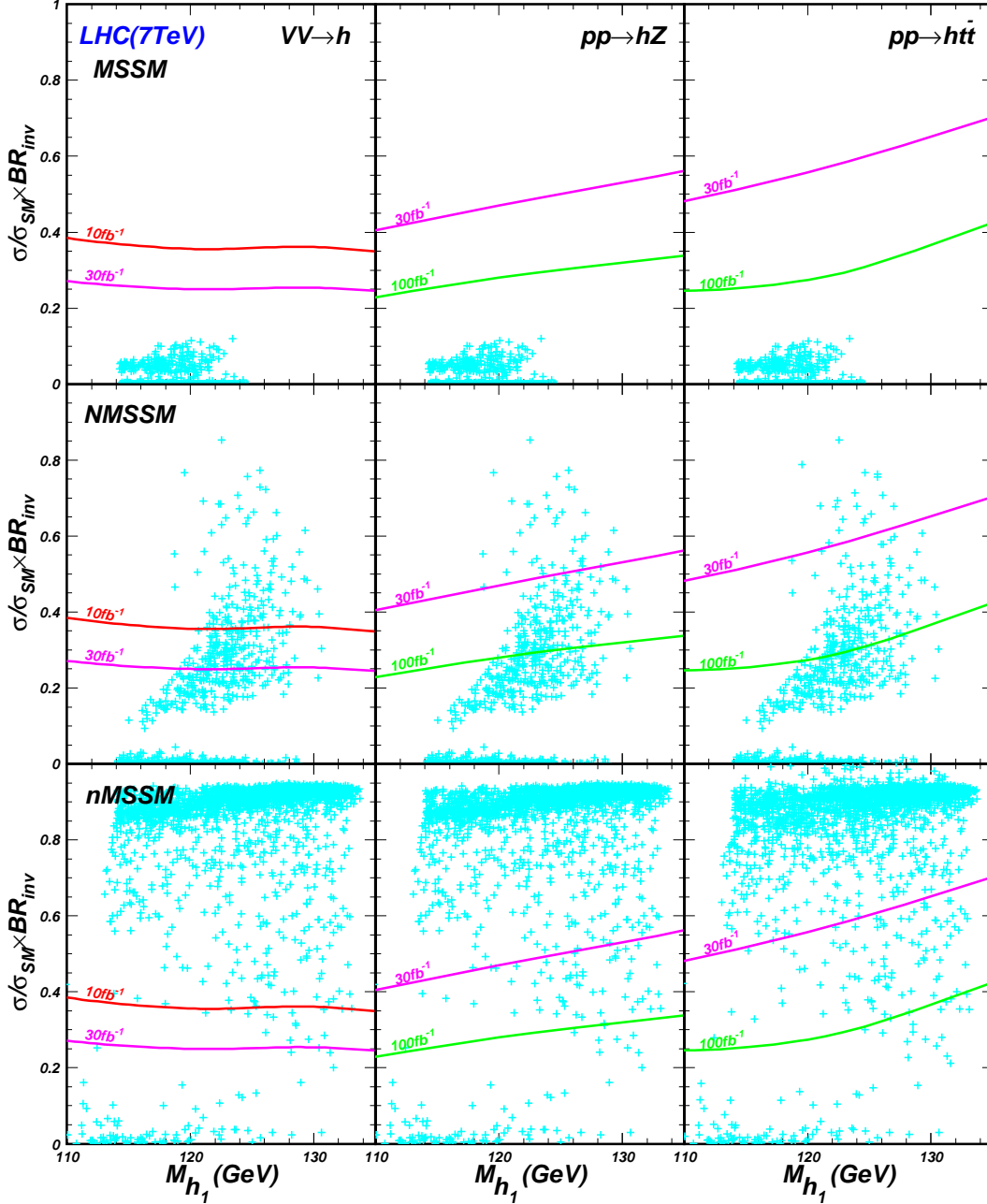


FIG. 2: Same as Fig.1, but showing the quantity $\frac{\sigma_{SUSY}}{\sigma_{SM}} \times Br(h_1 \rightarrow \chi_1^0 \chi_1^0)$ with σ_{SUSY} (σ_{SM}) being the SUSY (SM) Higgs production rates for the processes $VV \rightarrow h$, $pp \rightarrow hZ$ and $pp \rightarrow h t \bar{t}$. The solid curves show the 2σ sensitivity [23–25] of the ATLAS detector at the LHC (7 TeV) with 10 fb^{-1} , 30 fb^{-1} and 100 fb^{-1} (the region above each curve is the observable region).

- In a major part of the parameter space in the nMSSM, the decay $h_1 \rightarrow \chi_1^0 \chi_1^0$ is dominant over $h_1 \rightarrow b \bar{b}$ and thus observable at the LHC. The reason is the lightest neutralino is singlino-like and is always light, as can be seen from the neutralino mass matrix in Eq. (21). Also, from Eq. (18) we see that the coupling $g_{h_1 \chi_1^0 \chi_1^0}$ can be large

(near unity). Due to the new sizable decay $h_1 \rightarrow \chi_1^0 \chi_1^0$, the total width of the SM-like Higgs is greatly enlarged and thus its di-photon signal at the LHC is severely suppressed. So, if the recently observed di-photon signals at the LHC is verified in the near future, this model will be excluded.

IV. CONCLUSION

We examined the Higgs decay to neutralino dark matter in low energy SUSY by considering three different models: the MSSM, NMSSM and nMSSM. We considered current experimental constraints at 2σ level (including the muon $g - 2$ and the dark matter relic density) and scanned over the parameter space of each model. Then in the allowed parameter space we calculated the branching ratio of the SM-like Higgs decay to neutralino dark matter and examined its observability at the LHC by considering three production channels: the weak boson fusion $VV \rightarrow h$, the associated production with a Z-boson $pp \rightarrow hZ + X$ or a pair of top quarks $pp \rightarrow ht\bar{t} + X$. Our findings are: (i) In the MSSM such a decay is far below the detectable level; (ii) In the NMSSM it is accessible in a sizable part of parameter space; (iii) in the nMSSM it is detectable in a major part of the parameter space. (iv) When this invisible decay is sizable, the visible di-photon decay is suppressed. So, we conclude that at the LHC the interplay of detecting such an invisible decay and the visible di-photon decay may allow for a discrimination of different SUSY models.

Acknowledgement

Jingya Zhu thanks Lei Wu for helpful discussion. This work was supported in part by the National Natural Science Foundation of China (NNSFC) under grant Nos. 10821504, 11135003, 10775039, 11075045, by Specialized Research Fund for the Doctoral Program of Higher Education with grant No. 20104104110001, and by the Project of Knowledge Innovation Program (PKIP) of Chinese Academy of Sciences under grant No. KJCX2.YW.W10.

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